Bars and galaxy interactions in the Illustris simulation

Nicolas Peschken

with E. Lokas
Nicolaus Copernicus Astronomical Center, Warsaw

PNCG, Lyon, November 17, 2017
Introduction

- 30-60% of disc galaxies in the local universe host a bar in their center (Barazza et al. 2008, Nair & Abraham 2010, Laine et al. 2016)

- Bars can be formed in situ, or triggered by interactions with other galaxies: Tidal Bars

- Illustris: high resolution hydrodynamical cosmological simulation: $(106 \text{ Mpc})^3$, ~18 billion particles (Volgelsberger et al. 2015)
Bars in Illustris galaxies

Weak Bar

Strong Bar
Bars in Illustris galaxies

- Definition of bar strength:
  - Fourier moments:
    - $a_m(R) = \Sigma_i M_i \cos(m \phi_i)$
    - $b_m(R) = \Sigma_i M_i \sin(m \phi_i)$
  - Amplitude of $m=2$ component $A_2$: $A_2(R) = \frac{\sqrt{a_2^2 + b_2^2}}{a_0}$
  - $\rightarrow$ Bar Strength: $A_{2,\text{max}} = \max(A_2)$
Bars in Illustris galaxies

- Definition of bar strength:
  Fourier moments:
  \[ a_m(R) = \sum_i M_i \cos(m \phi_i) \]
  \[ b_m(R) = \sum_i M_i \sin(m \phi_i) \]
  Amplitude of m=2 component \( A_2 \): \( A_2(R) = \frac{\sqrt{a_2^2 + b_2^2}}{a_0} \)
  \( \rightarrow \) Bar Strength: \( A_{2,\text{max}} = \max(A_2) \)

- Presence of a Bar if \( A_{2,\text{max}} > 0.15 \):
  \( \rightarrow \sim 26\% \) of bars in local disc galaxies
  \( \rightarrow \) bar fraction \( \sim \) constant up to redshift 1
  \( \rightarrow \) bar fraction increases with total mass
Bars and interactions

Primary

Perturber
Bars and interactions
Bars and interactions
Bars and interactions

![Graph showing distance and bar strength over time.](image)
Bars and interactions

- Sample of 122 galaxies undergoing a fly-by interaction
- Bar strength increase happens right after the pericenter passage (0.29±0.14 Gyr)
Bars and interactions

- Sample of 122 galaxies undergoing a fly-by interaction

- Bar strength increase happens right after the pericenter passage (0.29±0.14 Gyr)

- In case of a pre-existing bar, the fly-by can:
  - Increase the bar strength
  - Decrease the bar strength
  - Have no effect

- Which parameters are responsible for these differences?
Bars and interactions

Orbital Angle

- Orbital Angle $\theta$: Angle between the orbital plane of the encounter, and the primary disc plane:
  - Prograde encounter:
    \[
    \cos(\theta) \sim 1
    \]
  - Retrograde encounter:
    \[
    \cos(\theta) \sim -1
    \]
Bars and interactions

Orbital Angle

- Orbital Angle $\theta$: Angle between the orbital plane of the encounter, and the primary disc plane:
  - Prograde encounter:
    $\cos(\theta) \sim 1$
  - Retrograde encounter:
    $\cos(\theta) \sim -1$

- Mostly pro-grade encounters create bars, or increase the bar strength
Bars and interactions

*Tidal Force*

- Strength of the interaction: Tidal Force (Lokas et al. 2016):

\[ TF = \frac{R_1 \times M_2}{D^3} \]

R1: scale-length of primary galaxy
M2: mass of the perturber
D: distance between the 2 galaxies
Bars and interactions

**Tidal Force**

- Strength of the interaction: Tidal Force (Lokas et al. 2016):
  \[ TF = \frac{R_1 \times M_2}{D^3} \]

  - $R_1$: scale-length of primary galaxy
  - $M_2$: mass of the perturber
  - $D$: distance between the 2 galaxies

- The stronger the interaction, the stronger the created bar: *weak* correlation

- Many other parameters can come into play: orbital angle, bar position angle, primary galaxy mass...
Conclusion

- Fraction of barred galaxies in Illustris is in the lower values of observations, increases with galaxy mass

- Tidally induced bars: bar is created right after the pericenter passage of an encounter

- Prograde orbits is the preferred way to create a bar or increase the bar strength

- The stronger the interaction, the stronger the created bar strength, but many other parameters can come into play

Thank you!